

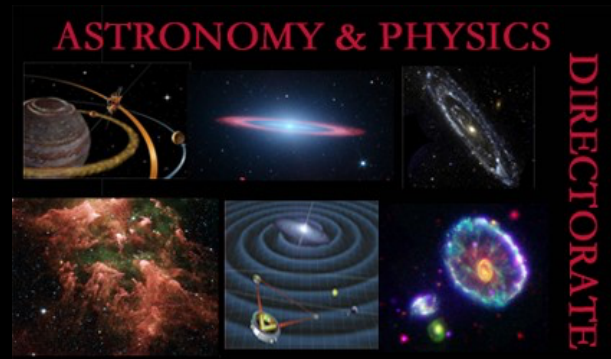


Jet Propulsion Laboratory
California Institute of Technology

Astronomy and Physics Technology at JPL

Todd Gaier

December 5, 2018



Science Focus (1 of 2)

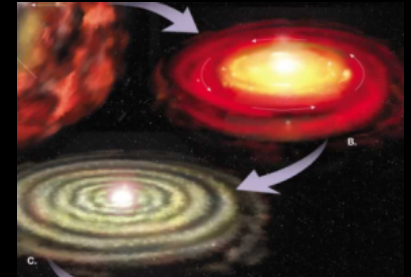
Exoplanetary Systems

- How do planetary systems form and evolve?
- How can we recognize life on planets outside the Solar System?
- Is there life elsewhere in the Universe?



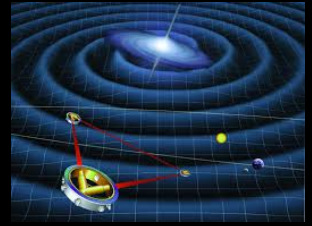
Long wavelength ($\lambda > \text{visible}$) Astronomy & Cosmology

- How did the Universe form and evolve?
 - What are the characteristics of dark matter and dark energy?
 - How is matter of all kinds distributed throughout the Universe?
 - What can the polarization of the cosmic microwave background reveal about the physics of inflation?
 - How do stars form?
 - How did galaxies and clusters of galaxies form and evolve?

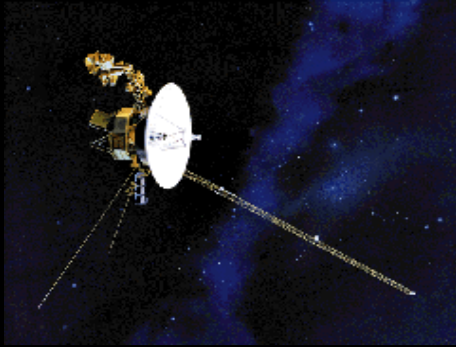


Science Focus (2 of 2)

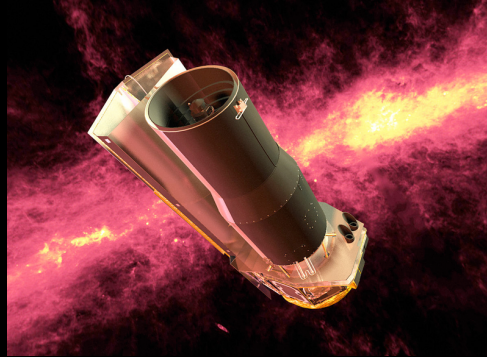
- **Gravitational Waves**
 - Use gravitational waves to study matter and energy in extreme environments that have never before been observable. Opening a “new window” on the universe and asking what do we see?



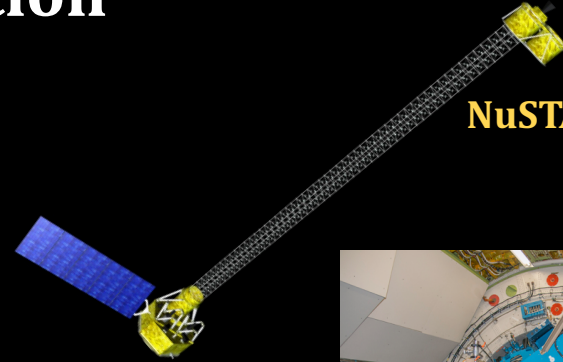
Current Missions and Instruments in Operation



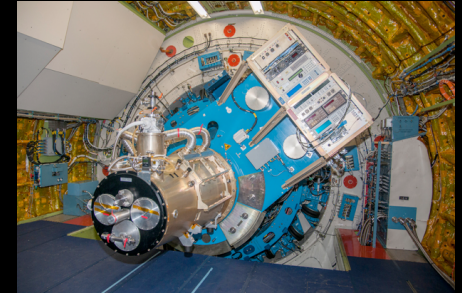
Two Voyagers 1977



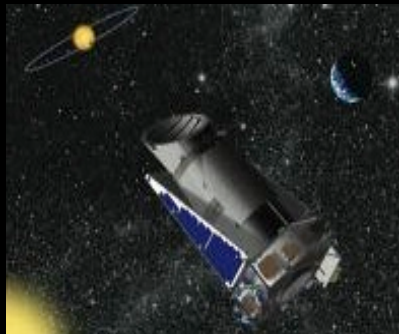
Spitzer 2003



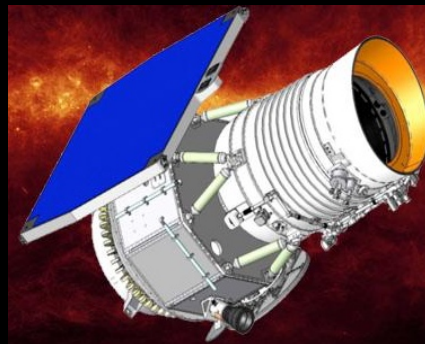
NuSTAR 2012



**HAWC+ on SOFIA
2016**



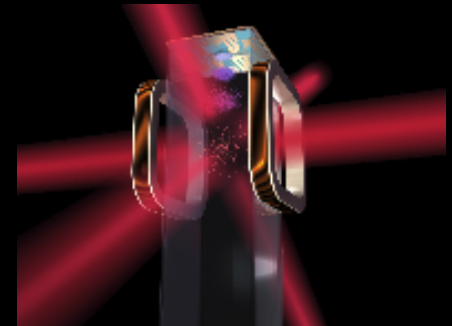
Kepler/K2 2009



**Wise 2009
(Restarted for NEOWISE 2013)**

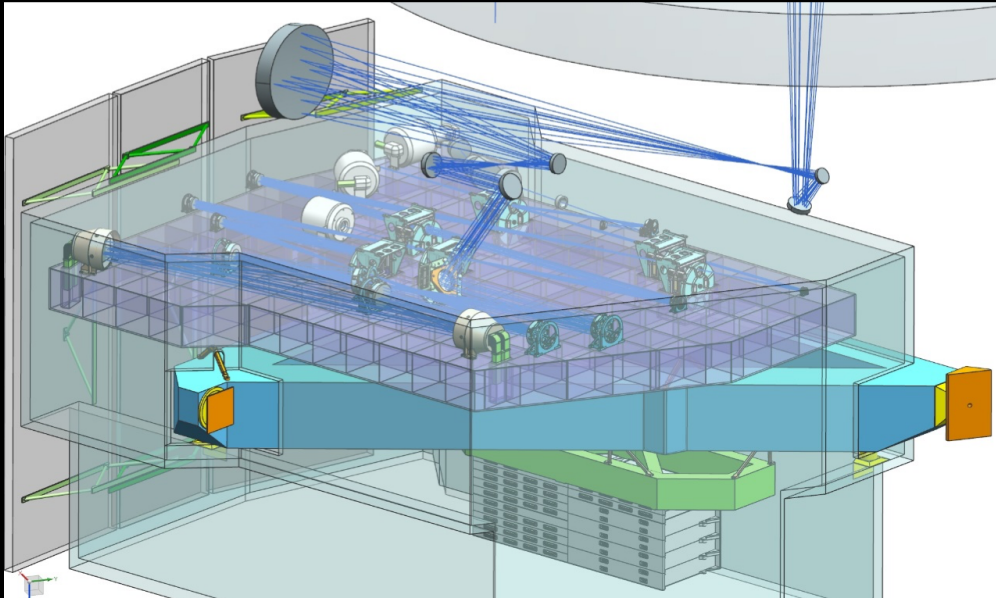


**ASTERIA Cubesat
2017**



CAL 2018

WFIRST Coronagraph Instrument (CGI)

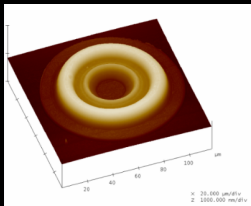


Critical Technology demonstration for the Future exo-earth missions:

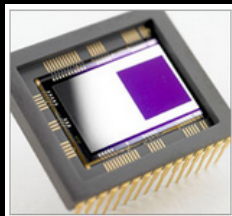
- First in-space demonstration of active wavefront sensing and control to 10's of pms using deformable mirrors (DM).
- First in-space use of ultra-low noise photon counting detectors to image exoplanets.

WFIRST Coronagraph Instrument (CGI) capabilities:

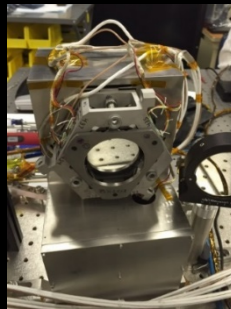
- A quantum leap ($\times 10^3$) compared to space (HST/ JWST) and ground state-of-the art (GPI/ SPHERE)
- Able to image exoplanets that are 1 billion times fainter than the host stars
- Available to support proposed GO programs.



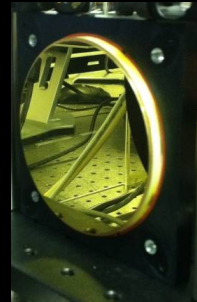
HLC mask image with an atomic force microscope



E2V EMCCD used in photon counting mode



Fast-steering mirror (FSM)

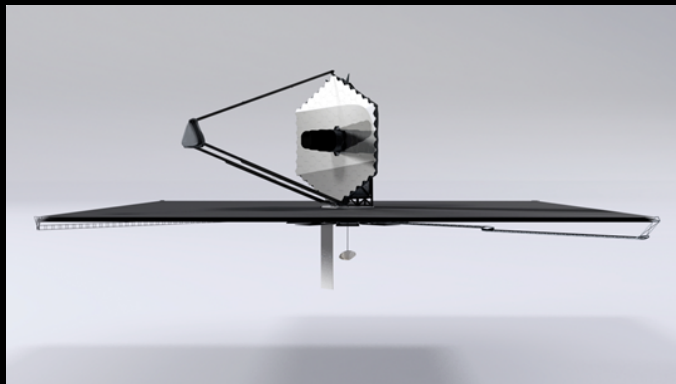


Xinetics 48 x 48 DM used in JPL's HCIT

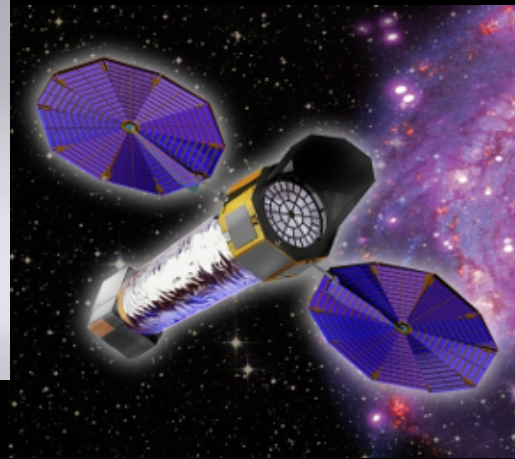
Astro2020 Large Mission Studies



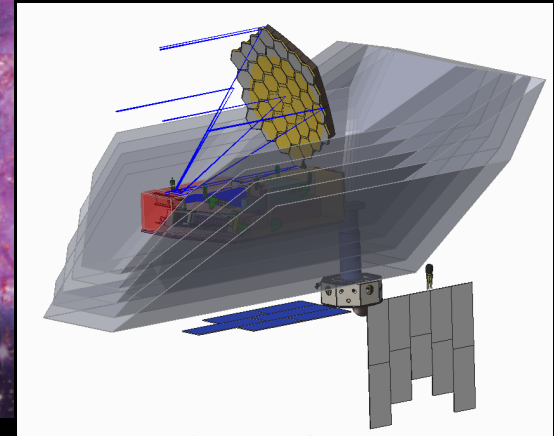
HABEX:
4 m telescope
Starshade + Coronagraph
for habitable exoplanets &
general science



LUVOIR: 9-15 m general
observatory also with
exoplanet direct imaging with
coronagraph



Lynx: high energy X-
ray observatory

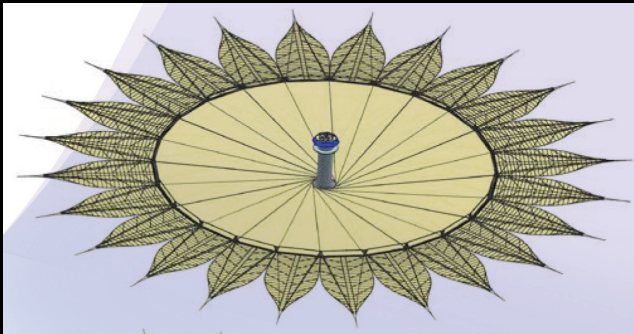


**Origins Space
Telescope:** 9 m
telescope @ 4K
temperature

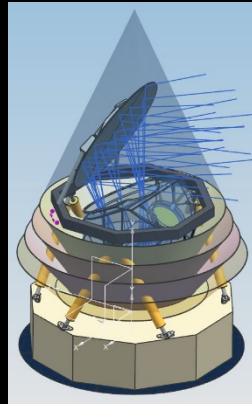
Astrophysics Probe Concepts May Create a New Opportunity

5 of 10 studies are working with JPL

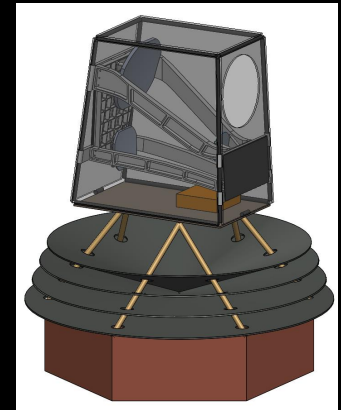
Starshade Rendezvous Probe could be the first in a new mission line



Starshade Rendezvous
PI: Sara Seager & Jeremy Kasdin

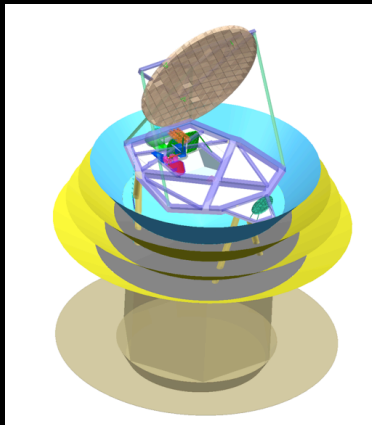


PICO - Inflation Probe
PI: Shaul Hanany



Cosmic Dawn
Intensity Mapper
PI: Asantha Cooray

Galaxy Evolution Probe
PI: Jason Glenn



Earthfinder PRV
PI: Peter Plavchan

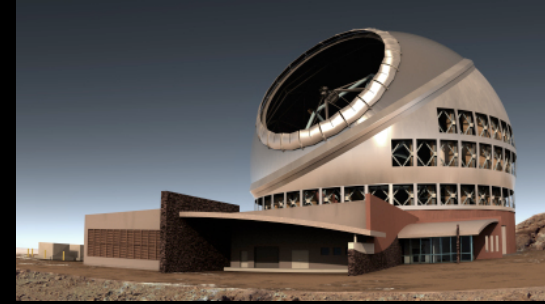
Ground Based Activities- Incubators for Flight Instruments



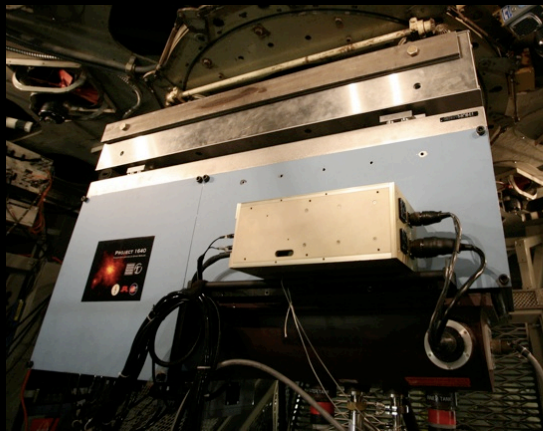
Vector Vortex Coronagraph & Keck Cosmic Wave Imager (KCWI)



Subaru Telescope Prime Focus Spectrograph



Thirty Meter Telescope

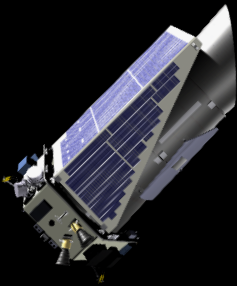


P1640 Calibrator & Coronagraph at Palomar

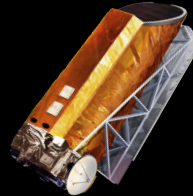
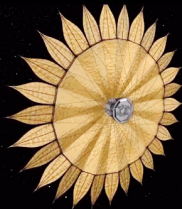
NASA Exoplanet Exploration Program

Space Missions and Mission Studies

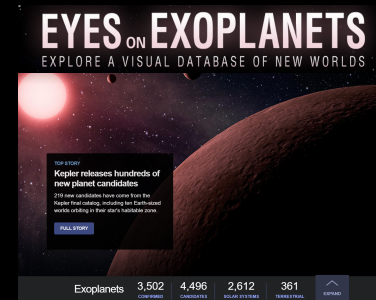
Kepler & K2



Probe-Scale Studies
Starshade *Coronagraph*



Communications

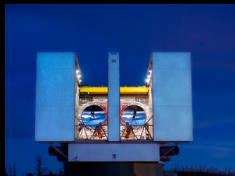


Supporting Research & Technology

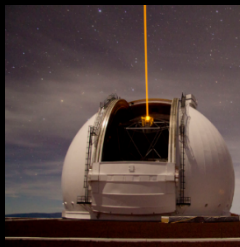
Key Sustaining Research



NN-EXPLORE



Large Binocular
Telescope Interferometer

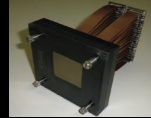


Keck Single
Aperture
Imaging & RV

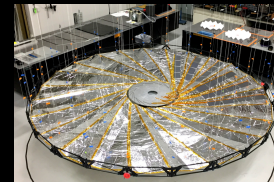
Occulting Masks



Technology Development Deformable Mirrors

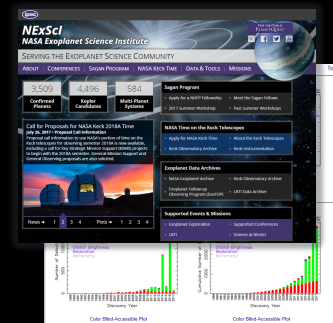


High-Contrast Imaging



Deployable Starshades

NASA Exoplanet Science Institute



Archives, Tools, Sagan Fellowships,
Professional Engagement

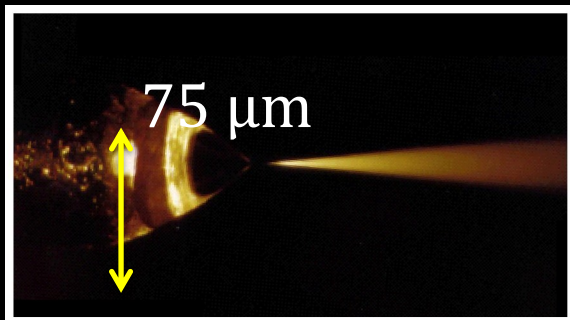
Technology Development

Our focus has been on future missions and precursor observations

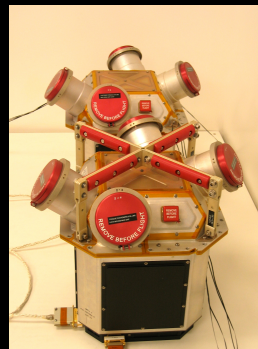
- Focus on future missions and precursor observations
 - Gravitational Waves
 - Microthrusters
 - Phasemeters
 - Exoplanets
 - Starshades, coronagraphs
 - PRV measurements
 - Astrophysics
 - Detector Technologies
 - UV detectors and coatings

Gravitational Waves-Microthrusters

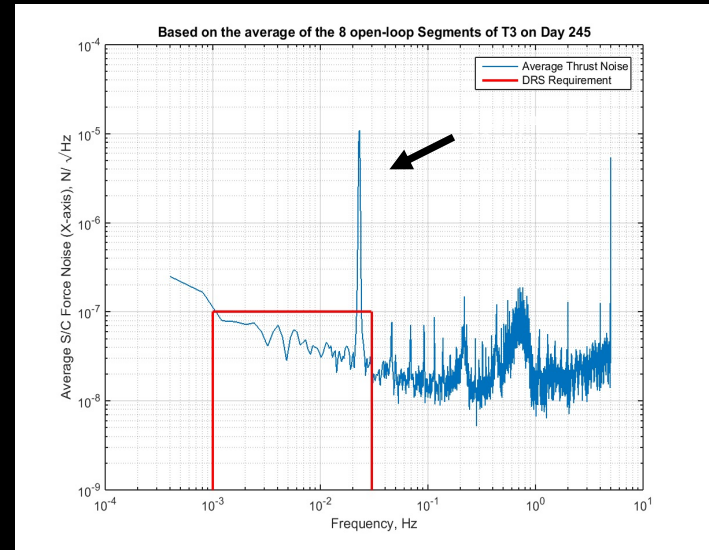
- ST-7 demonstrated drag-free spacecraft attitude and position control with precision and low-noise electrospray thrusters and control algorithms for a gravitational wave observatory.
- ST-7/DRS met all L1 mission requirements.
- At maximum thrust, ST7 can offset the mass equivalent to a mosquito sitting atop the spacecraft in increments of 100 nN.



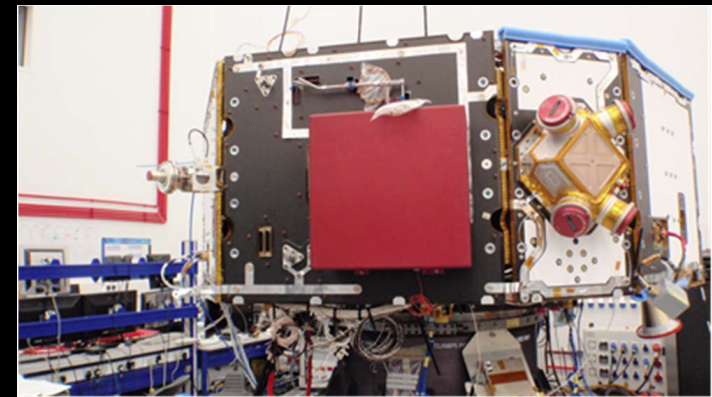
Colloid Electrospray Thruster (Busek Co, Inc)



Cluster of four Colloidal thrusters during testing at JPL



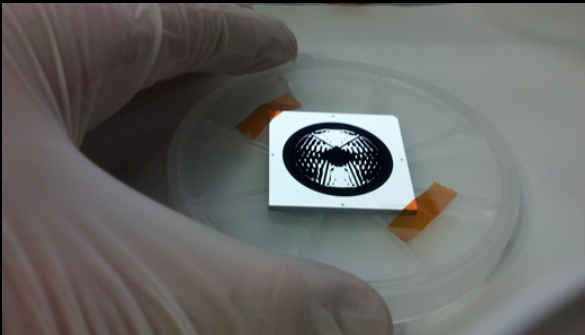
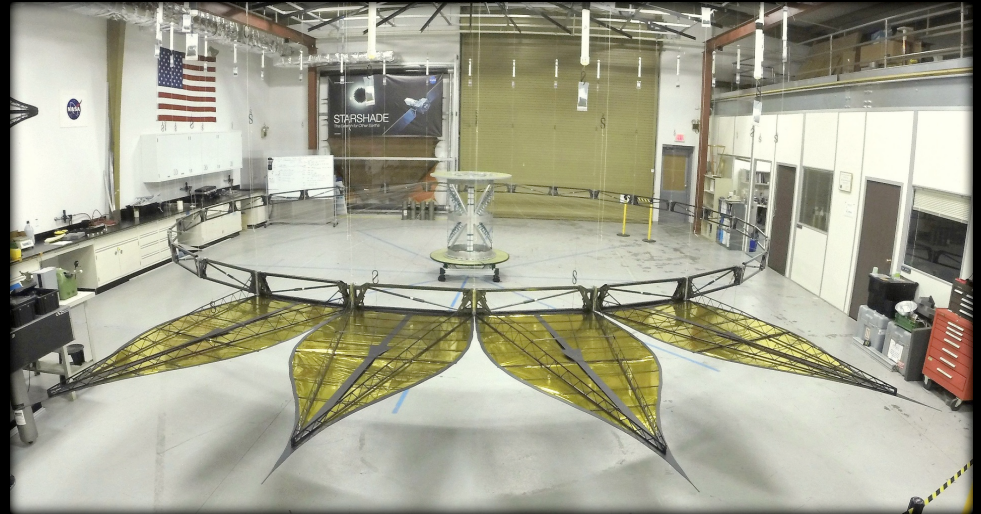
Amplitude spectral density of average thrust noise on the spacecraft with requirement in red.



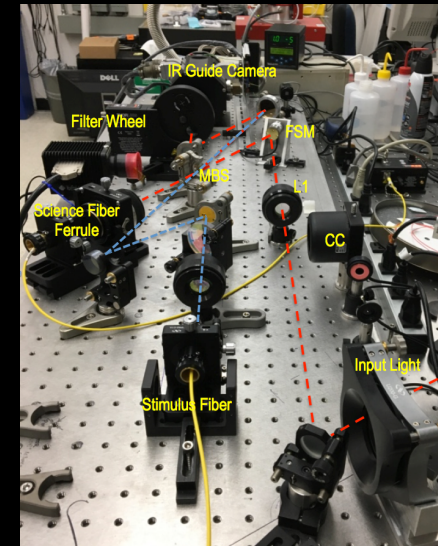
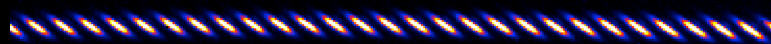
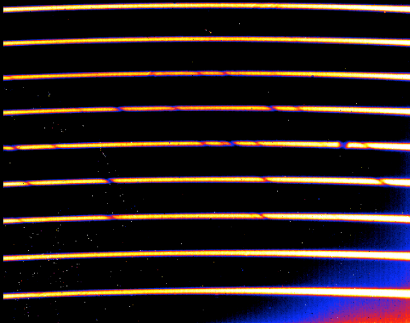
One of two Clusters mounted on the LISA Pathfinder spacecraft at Airbus, UK

Exoplanet Technologies

- Starshade development
 - Goal of TRL 5 by 2021
- Coronagraph Development

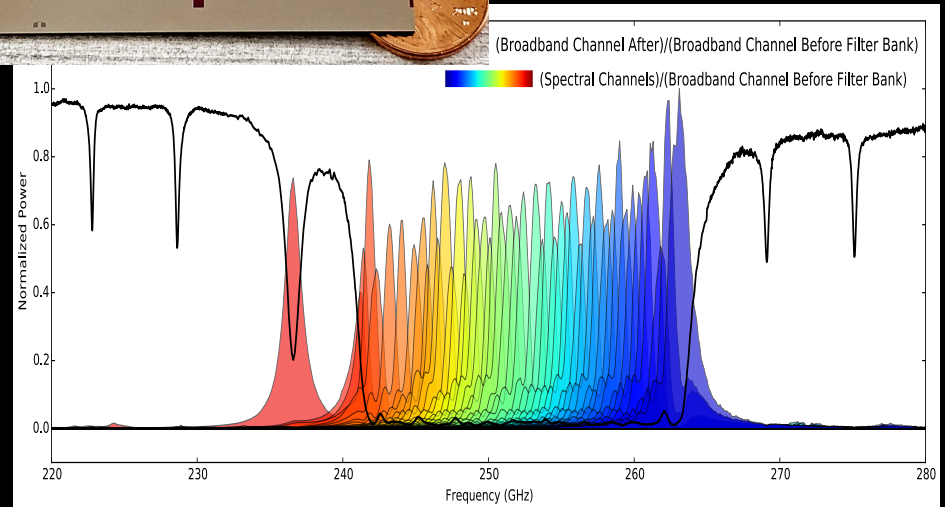
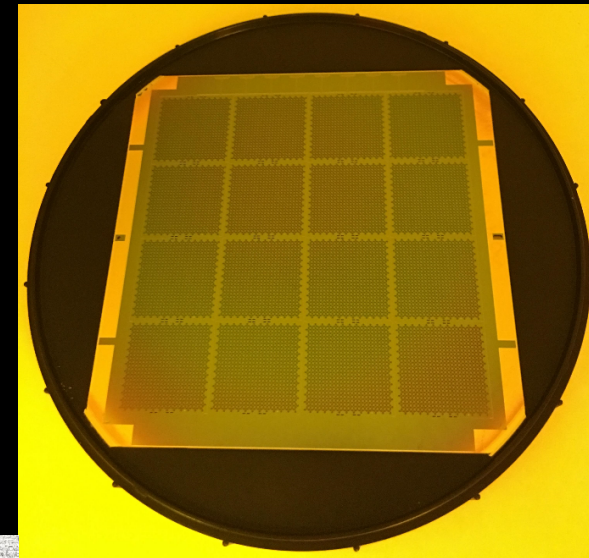
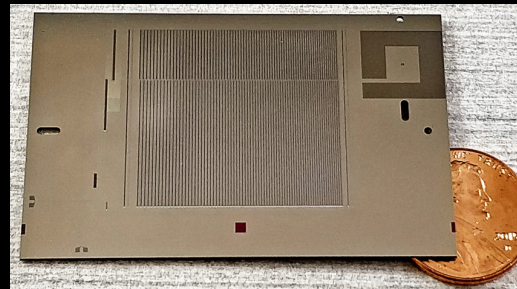
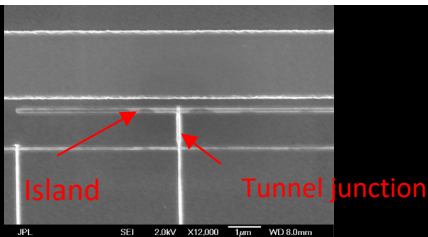
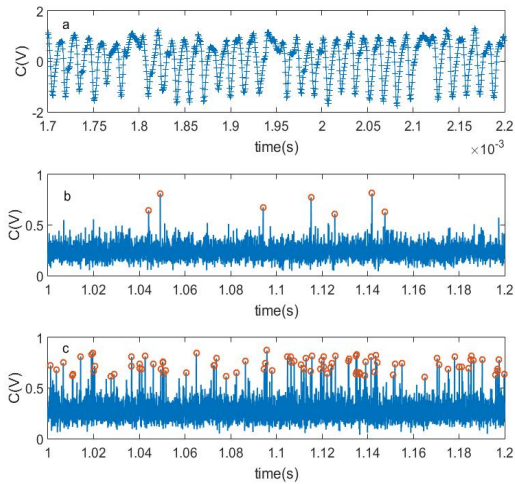


- Precision Radial Velocity Measurements
 - Palomar Radial Velocity Instrument (PARVI)



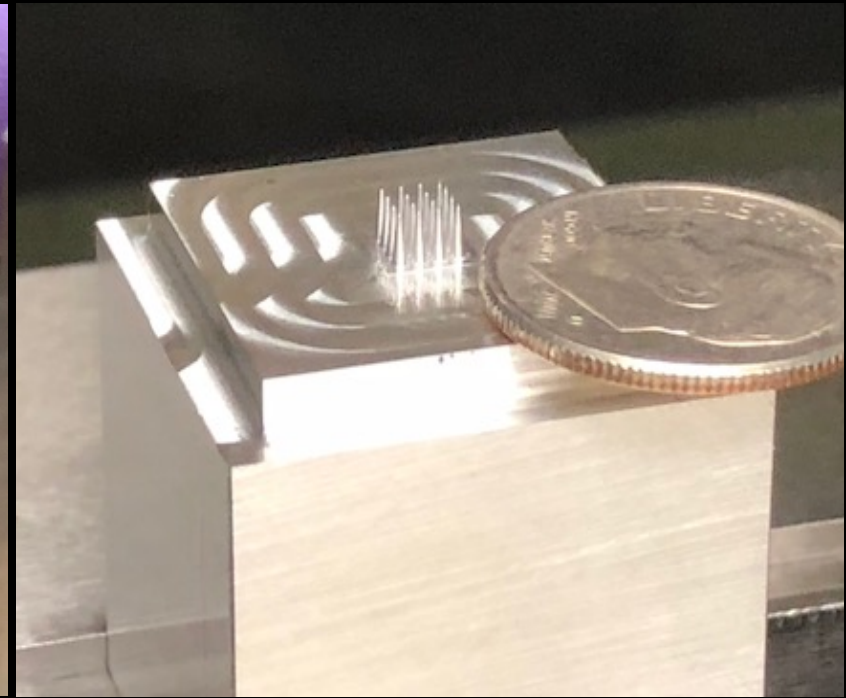
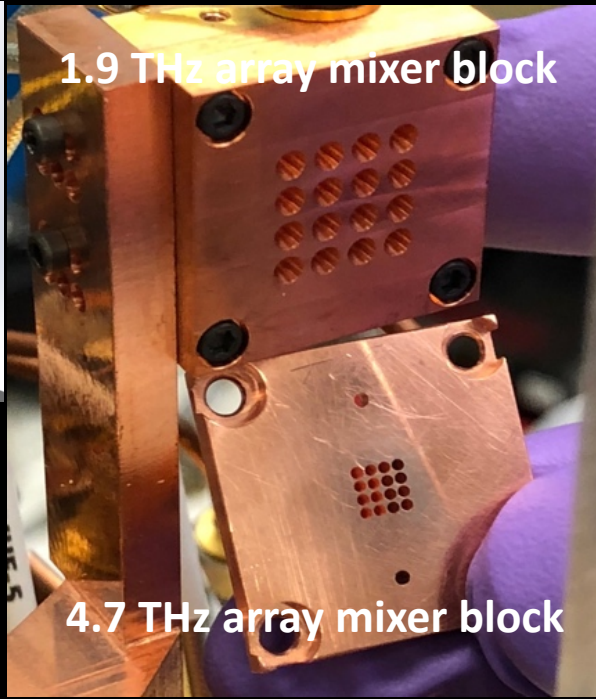
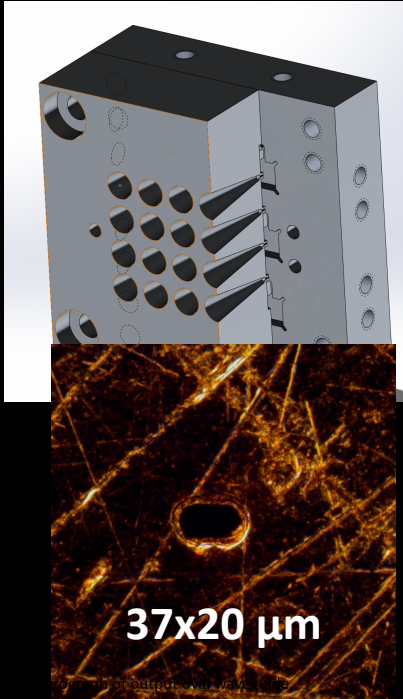
Detector Technologies

- mm, sub-mm direct detectors
 - TES bolometers for CMB
 - TES & MKID Spectrometers
 - Photon counting QCD bolometers



Detector Technologies

- Heterodyne detectors for spectroscopy- 1.9 THz HEB Array





Jet Propulsion Laboratory
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